The living morphology of the marine snails *Incisura remota* (Iredale, 1924) and *Sukashitrochus atkinsoni* (Tenison Woods, 1877) (Vetigastropoda: Scissurellidae)

Platon Vafiadis

Marine Research Group, Field Naturalists Club of Victoria, Locked Bag 3, PO Blackburn, Victoria, 3130.

Abstract
The collection of living specimens of the minute scissurellid gastropods *Incisura remota* (Iredale, 1924) and *Sukashitrochus atkinsoni* (Tenison Woods, 1877) has enabled, for the first time, a report on the external morphology of these species. General discussion of the family Scissurellidae is also provided. (*The Victorian Naturalist* **127** (6), 2010, 255–265)

Keywords: Head-foot, operculum, southern Australia.

Introduction

This paper reports on the living morphology of the scissurellid species *Incisura remota* (Iredale 1924) and *Sukashitrochus atkinsoni* (Tenison Woods 1877), both having been described on shell features alone (Tenison Woods 1877; Iredale 1924). The family Scissurellidae Gray 1847 is a world-wide family comprising minute molluscs whose shell possesses a slit in the body whorl. At maturity the slit remains open to the outer lip in some groups, whilst in others it is closed by the outer lip to form a foramen. A spiral groove called the selenizone represents earlier positions of the slit (exceptions are seen in the genera *Ariella* Bandel, 1986 which has a foramen but no selenizone, and *Coronadoa* Bartsch, 1946 which lacks selenizone and slit/foramen — see Geiger 2003; Geiger and Sasaki 2009). The slit facilitates exhalent water movement from the gills and release of waste and reproductive products (Wilson 1993) and is functionally analogous to the slit present in the Pleurotomariidae, the line of open holes in the Haliotidae, and the single hole, midline slit or internal dorsal groove of the Fissurellidae. Typical of such primitive groups, the scissurellid mantle cavity is bilaterally symmetrical, with paired gills and cardiac auricles, osphradia, hypobranchial glands and kidneys, but a single right gonad (Hickman 1998). Sexes are separate and fertilisation is external (Hickman 1998).

As at 2003 there were about 150 described Scissurellidae species, with many more awaiting description (Geiger 2003). Six species occur in Victorian waters: *Incisura remota*, *Incisura auriformis* Geiger & Jansen, 2004, *Scissurella cyprina* Cotton & Godfrey, 1938, *Sinezona beddomei* (Petterd 1884), *Sukashitrochus atkinsoni* and *Sukashitrochus pulcher* (Petterd 1884) (see Geiger and Jansen 2004b; Macpherson and Gabriel 1962).

Methods

Specimens were studied in dishes of seawater using a stereomicroscope at magnifications up to ×45, under fluorescent lighting. Photography used a Canon 300D digital SLR camera with a Canon MP-E65mm f/2.8 1-5X macro photo lens and ring flash, mounted on a stand with a remote shutter release. Shells were drawn at the Marine Invertebrate Laboratory, Museum Victoria, using a stereomicroscope fitted with a drawing tube. Specimens were preserved in 70% ethanol.

Taxonomic placement of examined species

The classification below for the species discussed herein is based on Bouchet and Rocroi (2005) and Geiger (2003). Generic diagnoses are provided by the latter, and synonomies by Geiger and Jansen (2004b).

Family Scissurellidae Gray, 1847
Subfamily Scissurellinae Gray, 1847
Genus *Incisura* Hedley, 1904
Type species: *Scissurella lytteltonensis* Smith, 1894
Incisura remota (Iredale, 1924)
Genus *Sukashitrochus* Habe & Kosuge, 1964
Type species: *Scissurella carinata* A. Adams, 1862
Sukashitrochus atkinsoni (Tenison Woods, 1877)

Abbreviations
a – examined alive; c – complete specimen (shell, operculum, and whole animal), preserved in 70% ethanol; LS: Lynton Stephens collection; MV – Museum Victoria; PV – Platon Vafiadis collection; s – empty shell (beach collected); SEM: scanning electron microscope.

Results
***Incisura remota* (Iredale, 1924) (Figs. 1–3)**
Material examined:
Victoria: Loch Ard Gorge, Victoria, on shallow sub-littoral algae, 16/2/2005 (2c, a, MV F113334). Popes Eye, Port Phillip Bay, Victoria, sub-tidal, 6-12m, on mixed benthic samples: 19/4/2008 (2c, MV F162108), 19/10/2008 (4c, a, MV F162109), 7/11/2009 (24c, MV F162110). Western Port Bay: Point Leo: 12s, 2005-2006 (LS); Honeysuckle Point, Shoreham: 10s, 2005-2006 (LS); Flinders: 2s, 2004-2005 (LS); Cat Bay, Phillip Island, Victoria, in shell sand: 4s, 18/10/2000 (PV); Silverleaves Beach, Phillip Island: 4s, 2006 (LS).

Shell
Length to 1.2mm (Wilson 1993, as *I. vincentiana* (Cotton 1945)). Shell thin, transparent to semi-opaque. Number of whorls approximately 2.5. Protoconch detail not discernible under light microscopy. Spire flattened, body whorl large and auriform in some specimens, in others more globose. Selenizone short, extending

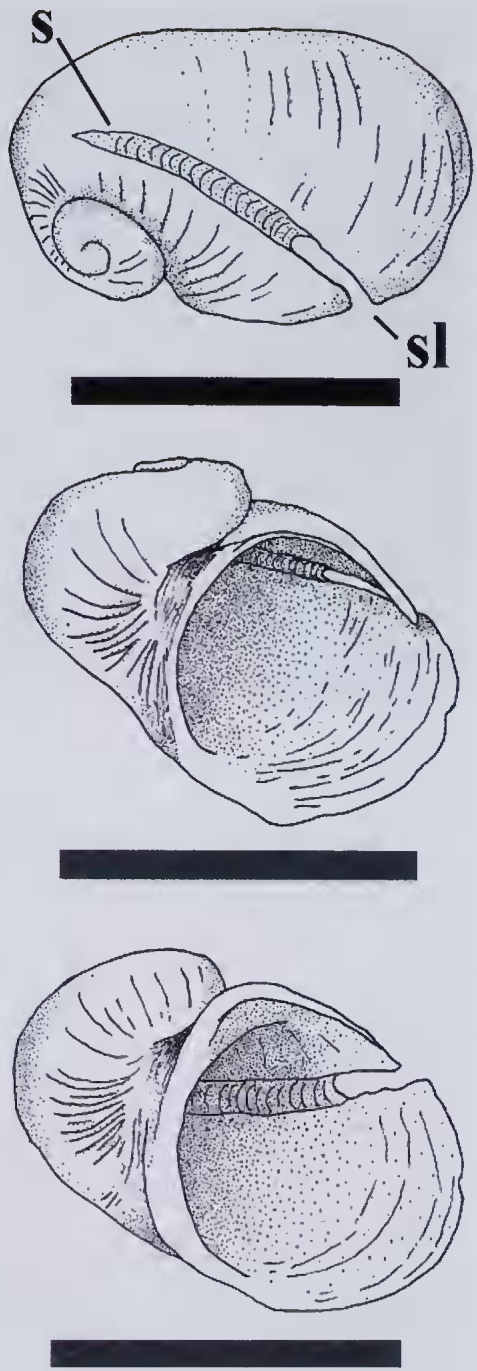

Fig. 1. Shell (Cat Bay, Phillip Island, Victoria, 18/10/2000, PV). Key: s—selenizone, sl—slit. All scale bars: 1.0mm. Drawings by Platon Vafiadis.

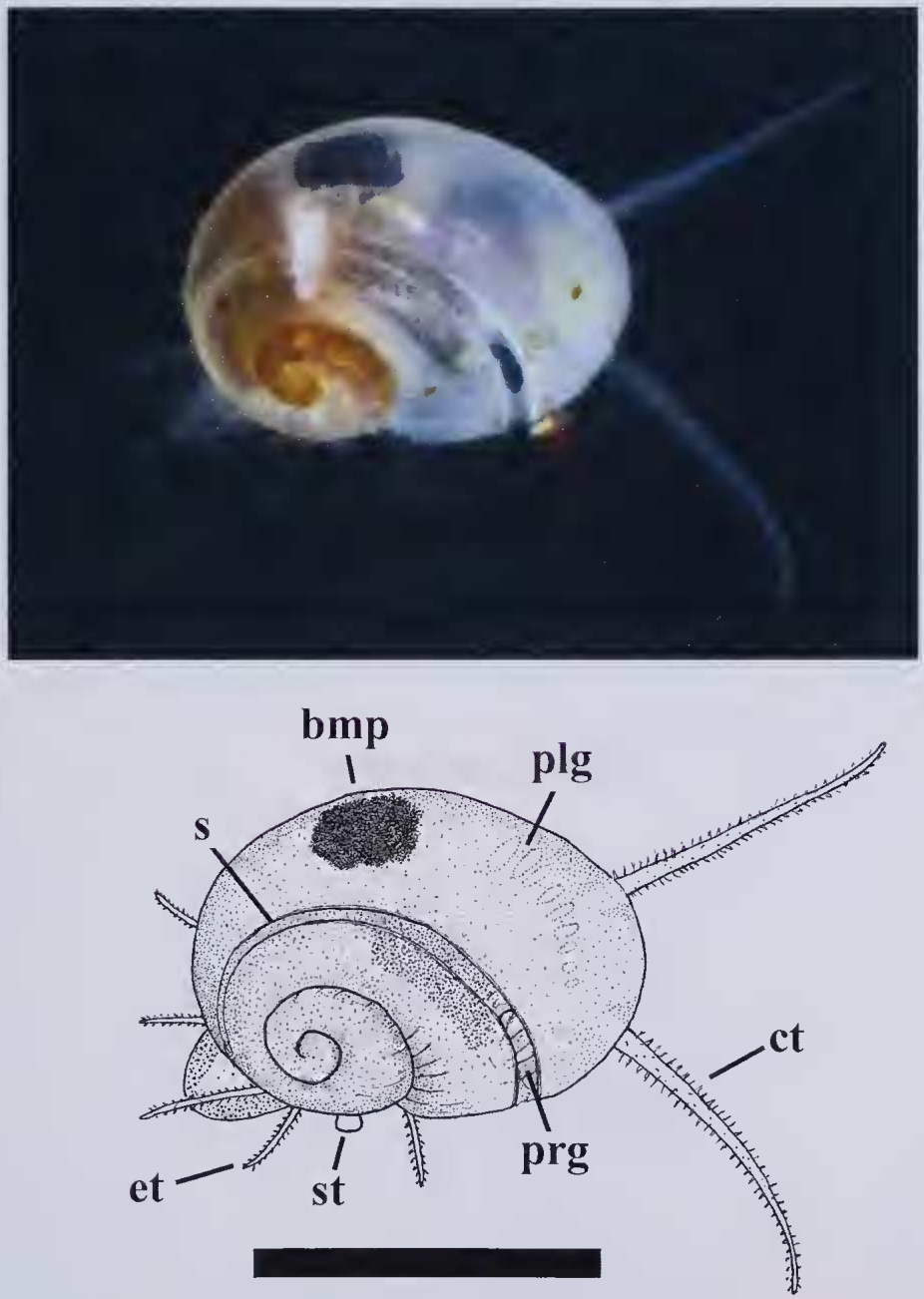

Fig. 2. *Incisura remota* (Iredale, 1924) Living animal, Popes Eye, Port Phillip Bay, Victoria (MV F162109). Key: bmp—black mantle pigmentation, ct—cephalic tentacle, et—epipodial tentacle, plg—pinnules of left gill, prg—pinnules of right gill, s—selenizone, st—smooth tentacle. Scale bar: 1.0mm. Photo/drawing by Platon Vafiadis.

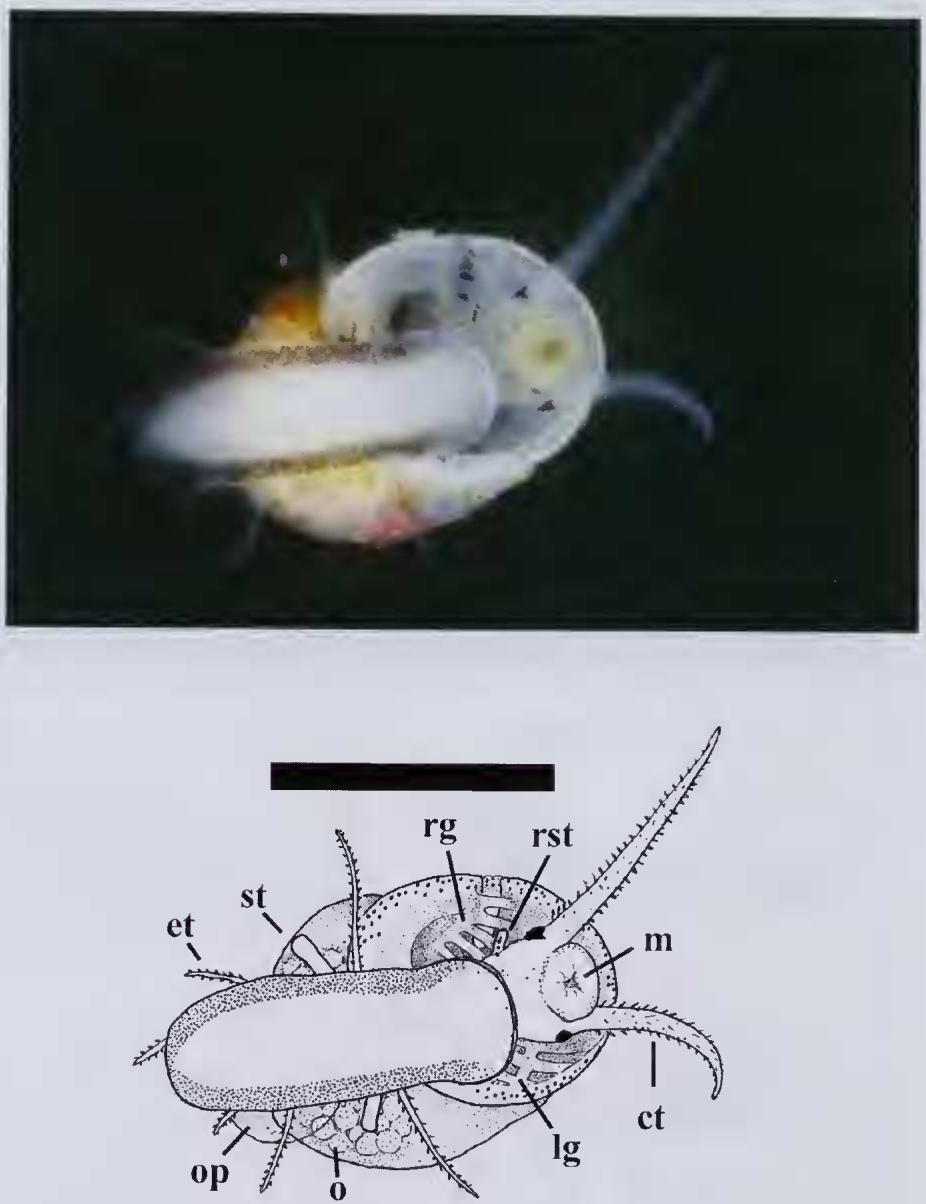

Fig. 3. *Incisura remota* (Iredale, 1924) Living animal, Popes Eye, Port Phillip Bay, Victoria (MV F162109), depicting a different specimen from that of figure 2. Key: ct—cephalic tentacle, et—epipodial tentacle, lg—left gill, m—mouth, o—ova, op—operculum, rg—right gill, rst—right subocular tentacle, st—smooth tentacle. Scale bar: 1.0mm. Photo/drawing by Platon Vafiadis.

to just over half a whorl in some specimens, not elevated, shallow. Slit open. Shell smooth except for microscopic growth lines and faint axial subsutural ribs. Umbilicus narrow, bordered by a low rib. Aperture large, ovate. Operculum thin, transparent, concentrically ridged and covers less than half of apertural area.

Animal

Animal opaque to semi-opaque white. Dense black mantle patch dorsally, persisting after alcohol preservation, with lighter black region around distal selenizone and yellow tissue beneath spire, all visible through shell. Cephalic tentacles long and densely micro-papillate. Eyes black, each at outer base of cephalic tentacle, no eye stalks. Snout and mouth yellowish. Snout rounded, displaying some black spotting, with the pharyngeal apparatus visible centrally. Peri-oral region and mantle edge around aperture speckled thinly in black. Head posterior and inferior to each eye bears short, blunt, smooth, club-like processes, one on each side (sometimes spotted in black), which Bourne (1910) calls sub-ocular tentacles, of which the right side in one specimen is duplicate, bearing two such processes closely applied to each other. Sub-ocular tentacle on right side more anteriorly placed compared to left. Dorsum of posterior head speckled finely and confluently brown. Neck lobes and cephalic lappets lacking. Two gills in roof of mantle cavity, stoutly bi-pinnate, left passing dorsally over the head and larger than right. No pallial tentacles observed protruding from slit. Eggs creamy yellow-white, visible though shell. Three pairs of tapering, micro-papillate epipodial tentacles, with a shorter, dorsoventrally flattened, blunt, smooth tentacle-like structure behind each first epipodial tentacle, its relationship to the latter not examined to detail, but may represent an enlarged basal sensory papilla (see also comments below under *S. atkinsoni*). Basal epipodial sensory papillae otherwise not seen, but could not be definitively excluded. Foot smoothly rounded at both ends. Margin of the dorsal foot lined with black, this under high magnification composed of fine, densely aggregated black spots. Dorsal foot and body marked with black on the right and left sides, and black pigmentation also present around opercular margin. Sole white and smooth. Anterior foot margin not examined closely, but photographs suggest it bears a transverse slit representing an anterior pedal gland. Foot can be longitudinally folded. When crawling, anterior foot does not project beyond snout; in some specimens, posterior foot projects beyond the shell margin. Animal crawls with a slightly jerky motion.

Distribution

Southern Australia, from central NSW south and west to Shark Bay, Western Australia, including Tasmania, at 0–50 m, on algae (Geiger and Jansen 2004b).

Remarks

Gieger (2003) and Geiger and Jansen (2004b) provide SEM images (of the same shell) of *I. remota*, including protoconch detail. *Incisura auriformis* Geiger & Jansen, 2004, the only other *Incisura* recorded from Victoria, is distinguishable by the closed slit (Geiger and Jansen 2004b). The New Zealand species *Incisura rosea* (Hedley, 1904) and *Incisura lytteltonensis* E. A. Smith, 1894 are also similar, but the former has peri-umbilical spiral lirae and a different protoconch microsculpture (Geiger and Jansen, 2004b) while the latter is more auriform with a very short slit and selenizone (see Geiger (2003) where, contrary to caption, *I remota* is in left column, and *I. lytteltonensis* in right column).

Bourne (1910) studied the New Zealand species *I. lytteltonensis*, noting sensory micro-papillae on each of the cephalic tentacles arranged in two rows on either side, three pairs of micro-papillate epipodial tentacles, micro-papillae on the mantle edges and digiform processes lining the mantle slit. Bourne (1910) reported no smooth processes between the first and second epipodial tentacles, as seen here in *I. remota*. The eyes of *I. lytteltonensis* bear a lens and a cornea, and the right sub-ocular tentacle in the single sectioned male was 'enlarged and spatulate in form' rather than digiform (Bourne, 1910). *I. lytteltonensis* has an anterior pedal gland opening 'on the anterior face of the foot in the groove between it and the lower surface of the snout', and many small posterior pedal glands, each opening via its own duct to the posterior sole (Bourne, 1910: 30). Observations herein on pedal gland openings in *I. remota* are insufficient, but photographs suggest that the anterior pedal gland opens to a transverse slit on the anterior foot margin, as in *S. atkinsoni* (see below). Bourne (1910) considered move-

ment in *I. lytteltonensis* of 12 mm in 15 minutes to be rapid. *I. remota* can comfortably move 1 mm in 10 seconds, or 90 mm in 15 minutes, assuming a sustained effort along a straight line.

***Sukashitrochus atkinsoni* (Tenison Woods, 1877) (Fig. 4–9)**

Material examined:

New South Wales: Huskisson: 2s, 8/3/2006 (LS); Quarantine Bay, Two Fold Bay: 1c, a (MV F162111), 1s (PV), both shallow sub-tidal, from amongst sand/silt and *Heterozostera* seagrass, 21/9/2009; Victoria: Western Port Bay: San Remo: 2s, 9/11/2004 (I.S); Point Leo: 7s, 2004-2006 (LS); Tasmania: Black River estuary: 10s, 17/10/2003 (PV).

Shell

Length to 2.5 mm (Wilson 1993). Depicted shell has 3 whorls. Dead shell white, semi-opaque. Living shell yellowish-white, semi opaque to opaque. Protoconch smooth on light microscopy. Selenizone extends a little over one whorl, edges prominently raised to form a concave groove; slit enclosed distally to form an elongate foramen. Whorls shouldered, selenizone comprising the shoulder. Area between suture and selenizone with spiral lirae and fine oblique axial sculpture. Whorl anterior to selenizone concave and bearing spiral ribs crossed by fine oblique-axial riblets, bordered abapically by a stronger spiral rib. Below the latter, spiral ridges encircle the prominent umbilicus, themselves crossed by fine oblique axial riblets. Umbilical floor a thin shelf with axial growth lines merging to the columella. Operculum circular, thin, transparent, bearing close concentric sculpture, about two thirds of apertural area.

Animal

Animal white, yellowish beneath apex. Snout bilobed, moderately long. Cephalic tentacles semi-translucent, long, tapering, retractile, somewhat dorso-ventrally flattened and densely micro-papillate. A black eye present at lateral base of each cephalic tentacle. No eye stalk. Postero-inferior to each eye is a solidly cylindrical, smooth, blunt lobe, similar in size on each side. Flattened neck lobes are lacking, as are cephalic lappets. Two gills in roof of mantle, visible on apertural inspection, left

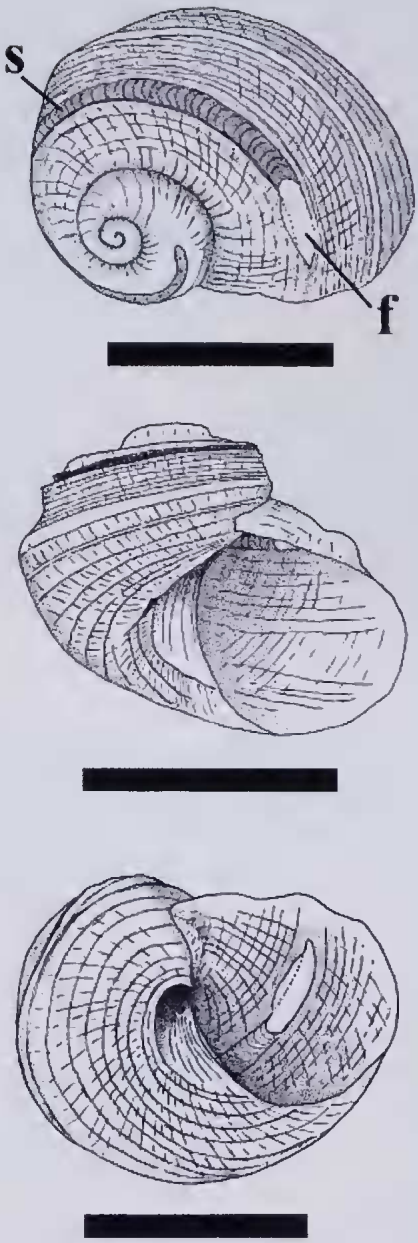

Fig. 4. *Sukashitrochus atkinsoni* (Tenison Woods, 1877) Shell (Black River estuary, Tasmania, 17/10/2003, PV). Key: s—selenizone, f—foramen. All scale bars: 1.0 mm. Drawings by Platon Vafiadis.

Fig. 5. *Sukashitrochus atkinsoni* (Tenison Woods, 1877) Living animal, Quarantine Bay, New South Wales (MV F162111). Photo by Platon Vafiadis.

gill passing dorsally over head, and larger than right. Gills thickly bi-pinnate and semi-opaque. Medial pinnules longer than lateral pinnules. Lateral pinnules of right gill very short and rudimentary; medial pinnules of right gill extend across distal portion of slit. No pallial tentacles observed. Three pairs of epipodial tentacles, these being thin, tapering, mobile, semi-translucent and densely micro-papillate. From the postero-lateral aspect of each first epipodial tentacle arises a dorso-ventrally flattened, translucent, smooth, bluntly rounded tentacle, long but shorter than first epipodial tentacle. This structure, absent on other epipodial tentacles, may be a (greatly enlarged) basal sensory papilla. Basal epipodial sensory papillae otherwise not seen, but could not be definitively excluded. Third pair of epipodial tentacles longer than anterior pairs. Foot bluntly square anteriorly, rounded posteriorly, with a deep transverse slit at anterior margin, representing a pedal gland. Sole smooth with no visible openings or slits. When crawling, posterior foot protrudes slightly behind posterior shell margin, and epipodial tentacles visible. Crawls with a smooth gliding motion.

Distribution

Found mainly in temperate southern Australia, but ranges from north-east Queensland south and west to north-east Western Australia, including Tasmania, at 0–165 m, under stones, on algae (Geiger and Jansen 2004b) or among *Heterozostera* seagrass (as herein).

Remarks

Geiger and Jansen (2004b:48–50) provide SEM images of several specimens of *S. atkinsoni* including protoconch detail.

Haszprunar (1988) reported on the animal of a *Sukashitrochus* sp., noting large black eyes on short eyestalks, a small 'setose tentacle' (termed epipodial) fused to each eyestalk, with three epipodial tentacles behind this, an operculum on the left side of the foot, and a laterally compressed metapodium which, when flapped with the animal inverted, could generate bursts of swimming. Hasegawa (2004) observed similar swimming behaviour in Japan in *Scissurella staminea* (A. Adams 1862), an undescribed *Scissurella* and *Sinezona plicata* (Hedley, 1899), noting the animals to have

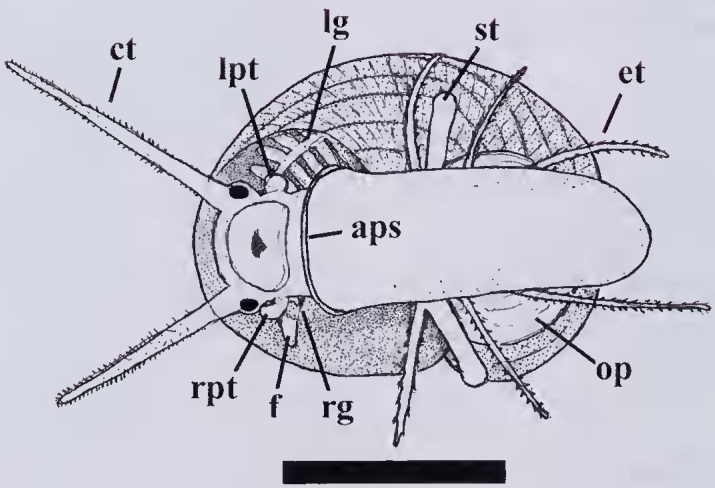

Fig. 6. *Sukashitrochus atkinsoni* (Tenison Woods, 1877) Living animal, Quarantine Bay, New South Wales (MV F162111). Key: aps—anterior pedal slit, ct—cephalic tentacle, et—epipodial tentacle, f—foramen, lg—left gill, lpt—left post-optic tentacle, op—operculum, rg—right gill, rpt—right post-optic tentacle, st—smooth tentacle. Scale bar: 1.0mm. (Photo/drawing by Platon Vafiadis.)

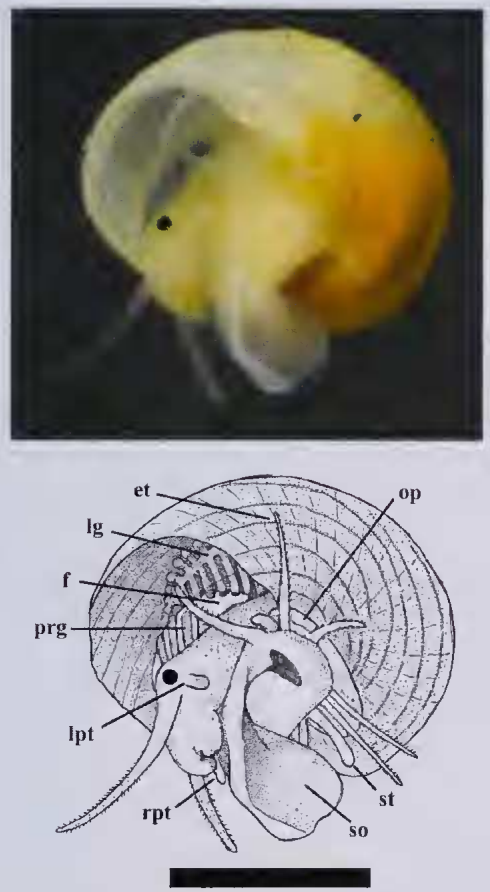

Fig. 7. *Sukashitrochus atkinsoni* (Tenison Woods, 1877) Living animal, Quarantine Bay, New South Wales (MV F162111). Key: et—epipodial tentacle, f—foramen, lg—left gill, lpt—left post-optic tentacle, op—operculum, prg—pinnules of right gill, rpt—right post-optic tentacle, so—sole, st—smooth tentacle. Scale bar: 1.0mm. (Photo/drawing by Platon Vafiadis.)

large eyes and a laterally compressed foot with operculum on the left side. Hickman and Porter (2007) reported swimming in *Scissurella spinosa* Geiger & Jansen, 2004, noting it to have a white head and foot, large black eyes on short eyestalks, reddish-orange eggs in females, a fine line of purple-black pigment granules bordering the sole, and a laterally compressed metapodium (see also Discussion below). Although Geiger (2003) did not dispute Haszprunar's (1988) generic diagnosis of his *Sukashitrochus*, it is questionable for three reasons: first, the similarity of his animal to the swimming species of other genera as discussed; second, Haszprunar's (1988) lack of mention of spiral basal keels on his shell; and third, the lack in *S. atkinsoni*, as reported herein, of a modified foot, left-sided opercular displacement and swimming behaviour.

Discussion and concluding remarks

Little is known on the anatomy, biology and ecology of scissurellid gastropods, with most data based on shell and radula characteristics. Information is, however, gradually becoming available. Reports on swimming in scissurellids (Haszprunar 1988; Hasegawa 2004; Hickman and Porter 2007) note the animals attracted in large numbers to light in order to spawn (Hasegawa, 2004; Hickman and Porter, 2007). Hickman and Porter (2007) observed mass swarming (tens of thousands of snails) and mass broadcast spawning of *S. spinosa* in and around light traps in French Polynesia, the traps being 2 metres off the sea floor. The animals swam to them using the modified metapodium. Male to female numbers were equal. Shells were not sexually dimorphic. Females bore red-orange eggs released from the apertural margin only, whilst males released pale white clouds of sperm through both the foramen and apertural margin (Hickman and Porter 2007). Fifty specimens of *Sinezona plicata* (Hedley, 1899) were also collected in the light traps (Hickman and Porter 2007), confirming Hasegawa's (2004) observation of swimming in this species. Whether Hasegawa's (2004) undescribed swimming *Scissurella* was *S. spinosa* is speculative.

Hickman (1999) reported sexual dimorphism and contact pairing in active *I. auriformis* from Rottnest Island, Western Australia, with the smaller male positioned on the spire and upper body whorl (but adapical the selenizone) of the female, with the right or both cephalic tentacles extending across the female's foramen but never obstructing it (suggesting that eggs are fertilised as they emerge through the foramen). The smaller males lacked selenizone and slit/

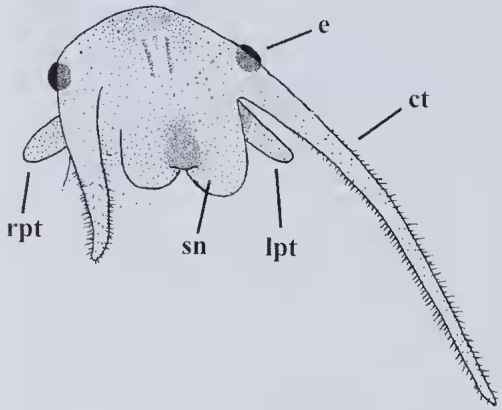

Fig. 8. *Sukashitrochus atkinsoni* (Tenison Woods, 1877) Living animal, Quarantine Bay, New South Wales (MV F162111).
Key: ct—cephalic tentacle, e—eye, lpt—left post-optic tentacle, rpt—right post-optic tentacle, sn—snout. Drawing by Platon Vafiadis.

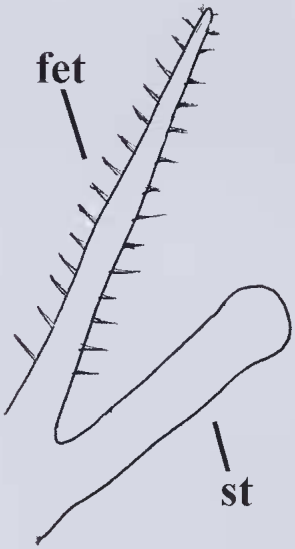

Fig. 9. *Sukashitrochus atkinsoni* (Tenison Woods, 1877) Living animal, Quarantine Bay, New South Wales (MV 162111). Schematic diagram, ventral aspect, of left front epipodial and smooth tentacle.
Key: fet—front left epipodial tentacle, st—smooth tentacle. Drawing by Platon Vafiadis.

foramen, but females at comparative sizes also lacked these features. Possible causes of sexual dimorphism include differential growth rates, differential mortality, or protandry (Hickman, 1999). Burn (2010, unpubl. pers. comm.) observed similar contact pairing in *I. remota* from subtidal algal samples collected 5 February 2006 from Popes Eye, Port Phillip Bay, but notes were not taken on the relative features of the smaller, presumably male, shell.

The Anatomidae McLean 1989, recently separated from Scissurellidae (Geiger and Jansen 2004a), are a closely allied family for which anatomical information is available for comparison to the work herein. The Anatomidae have an open slit with the selenizone placed peripherally on the whorl, and, with rare exceptions, occur only in deep water (Geiger and Sasaki, 2009). They are represented in Victoria by *Anatoma tobeyoides* Geiger & Jansen, 2004 and *Anatoma australis* (Hedley, 1903), species known only from their shell (Geiger and Jansen, 2004a). The South African *Anatoma yaroni* Herbert, 1986 has papillate cephalic tentacles, with each eye on a very short stalk, a non-papillate post-optic tentacle (analogous to Bourne's (1910) subocular tentacle), a non-papillate neck tentacle (interpreted as analogous to the neck lobes of other vetigastropods), one to two micro-papillate pallial tentacles that can protrude through the slit, three pairs of micro-papillate epipodial tentacles (the most anterior

tentacle dividing basally to form 'two tentacles', presumably of similar morphology) with the second and third each bearing a large basal sensory papilla, a papillate mantle edge bordering the slit and two delicate gills similar to those of the northern hemisphere *Anatoma crispata* (Fleming, 1828) (Herbert, 1986). *Anatoma crispata* bears micro-papillate cephalic tentacles, smooth post-optic and neck tentacles (one of each), interpreted as epipodial by Fretter and Graham (1962), and, additionally, at least three pairs of micro-papillate epipodial tentacles, micro-papillate pallial tentacles that can protrude through the slit and two delicate gills with filamentous pinnules (Fretter and Graham 1962). Geiger (2006) shows the preserved animal of *Anatoma janetae* Geiger, 2006 having four pairs of epipodial tentacles and no eyes (owing to its existence at great depth).

It is hoped that simple observations as presented here will contribute to a better understanding of the overall biology of the minute but striking species of this family.

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